INTEGRATION OF IMPORTANCE-PERFORMANCE ANALYSIS AND FUZZY DEMATEL

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ABSTRACT

The traditional Importance-Performance Analysis (IPA) assumes that quality attributes are independent variables, and presupposes that explicit customers' response data is used for assessing the importance and performance of quality attributes. Under this supposition, when the quality attribute has explicit causation data, the traditional IPA cannot correctly provide importance and priority of improvement. Moreover, the influential degree of the traditional quality attributes is emphasized as maximum degree. This study employs regression analysis and the fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL), which consider the fuzziness of human thinking, to calculate the causal relationship and the influential degree among each quality attribute, and then proposes a new methodology of decision analysis, which modifies the traditional IPA and obtains the accurate importance and the improvement the quality attributes. In this study, a Taiwanese bank is an empirical case study, which illustrates the application and the effectiveness of integrating fuzzy DEMATEL and IPA.

KEYWORDS

Importance-Performance Analysis; Multiple Regression Analysis; Decision Making Trial and Evaluation Laboratory; Fuzzy Theory

1. INTRODUCTION

Martilla and James [18] first used Importance-Performance Analysis (IPA) method in the marketing strategy on development companies, which emphasized that the method is low-cost, easy to apply, and with a better focus on strategies. The IPA method is easy to understand, and companies can analyze their strengths and shortcomings from the results of the method in order to confirm their business opportunities and strategic direction to improve, so the IPA not only has been widely used in analyzing business strategies of every industry, but also has become an important research tool for service quality attributes. For example, Xiuli and Chu [30] used IPA approach for customer satisfaction evaluation supporting PSS design. Hu, Chiu, Cheng, and Yen

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[8] applied the IPA and DEMATEL models to improve the order-winner criteria. Deng, Chen and Pei [2] used IPA method to improve the management of the quality of hot spring hotels. Tonge and Moore [27] used IPA method and gap analysis in assessment of marine environmental protection management. Huang, Wu and Hsu [10] used IPA method to probe the national highways' the long-range passengers satisfaction of service quality attributes. Levenburg and Magal [16] used IPA method to establish e-commerce strategies and resource allocation.

These scholars have contributed to IPA method in many ways. However, the design of the traditional IPA survey locks consideration of the fuzziness of human thinking. The questionnaire of the survey often asks respondents to choose one answer from the selected semantic wording, which results in an integer value, the analyzed results are distorted, and leads to relationing errors. Moreover, the traditional IPA presupposes that explicit customers' response data is used for assessing the importance and performance of quality characteristics and that each quality characteristic is an independent variable, which does not take implicit phenomena of human psychological decision-making behavior and causal relationship between the quality attributes in the positive information into account, so the traditional IPA model cannot provide accurate importance analysis and the priority ranking for improvement. This study proposes a new methodology of decision analysis, in addition to the use of multiple regression analysis method to establish the relationship between quality attributes and overall satisfaction and importance; considering the fuzziness of human thinking, this study employs fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) to analyze the causal relationship between the quality attributes and the degree of their mutual influence in order to in order to modify the importance of quality attributes and the priority ranking for improvement based on the traditional IPA model, which can be a reference for managers to deal with complicated practical issues. A Taiwanese bank is an empirical case study in this research, which illustrates the application and the effectiveness of integrating fuzzy DEMATEL and IPA.

2. IPA

2.1 IPA Review

IPA, proposed by Martilla and James [18], assists managers to confirm the quality attributes which can achieve the results of high customer satisfaction, and then to develop effective marketing strategies. IPA is a two-dimensional matrix based on customer-perceived importance of quality attributes and attribute performance. In the matrix, quality attributes of performance and importance are axis X and axis Y, and the split values axis X and axis Y are the total average of each quality attributes' performance and importance. Therefore, quality attributes are divided into four quadrants, defined as: (1) Concentrate here: customers think highly of the quality attributes, but they are not satisfied with the quality. (2) Keep up the good work: customers think highly toward the importance of products or service quality attributes, and the level of companies' performance is high. (3) Low priority: the performance of companies' products and service quality attributes is low, and the importance of customers' awareness is also low. (4) Possible overkill: the performance of companies' products and service quality attributes is high, but the importance of customers' awareness is low. According to the quadrants of quality attributes, managers know clearly that the current delivering service quality attributes of their company are their advantages or disadvantages, and then to make their strategies to each quality attribute of every quadrant. Comparing to other management methods, IPA not only implement surveys for the degree of acceptance about importance and performance of quality attributes, but also provide statistical analysis of coefficient of practical to understand practical importance and influence.

Although IPA method is easy to be applied and its results are obvious to be interpreted, there are still hidden problems. Therefore, after Martilla and James' [18] IPA method published, many scholars have proposed modified models. For example: Deng et al. [2] believed that general statistical methods to obtain importance needed many basic assumptions, so he managed to use neural-liked method to obtain importance and to correct the IPA model. Matzler et al. [18] thought that the organization's overall satisfaction with the performance of quality attributes is a function of the degree. Matzler et al. [19] study suggests the importance of quality attributes is a function of performance quality attributes. Matzler and Sauerwein [20] that the degree of importance is the performance of a function to show the overall degree of satisfaction as independent variables as dependent variables to do multiple regression analysis, the obtained regression equation, the regression coefficient of the important quality attributes as the degree to re-establishment of importance and performance analysis matrix. Lee et al. [13] also used multiple regression analysis to establish the overall satisfaction with the quality characteristic of the implicit importance to the quality attributes of the gap analysis and calculation performance

While the above research and discovery of the theory and application of IPA significant contribution, only a few studies explore the causal relationship between the quality attributes and influence each other. Therefore, in addition to the theories of Matzler and Sauerwein [20], which is that the function of satisfaction quality attributes is implicit importance, and Lee, Li, Yen, and Huang [14], which is employed multiple regression analysis to establish quality attributes and the overall satisfaction of the implicit importance, this study also takes take the fuzziness of human thinking into consideration to redesign questionnaires. In the redesigned questionnaires, ambiguous words are used to understand the causal relationship and mutual influence of quality attributes, and then to modify the importance of quality attributes and the priorities of improvements, which can prevent companies from making wrong decisions.

2.2 Modified IPA Model

From IPA literatures, this study modifies the more relationable IPA model; as well as the causal relationship and mutual influence of each quality attribute, which were not studied by previous researches, this study employs the fuzzy DEMATEL to revalue the importance and to identify core issues for making quality attributes of the improvement and the allocation of resources more rational. In the study, proposed the modified IPA model and fuzzy DEMATEL, there are the following topics to be discussed: (1) multiple regression analysis is used to establish the performance of each quality attribute and the equation of function of overall satisfaction, which the regression coefficients are viewed as the assessed values of each importance quality attribute; (2) IPA matrix is based on the implicit importance and performance to establish the vertical axis and horizontal axis; (3) fuzzy DEMATEL is employed to analyze the causal relationship and mutual influence of each quality attribute; (4) integration of IPA and fuzzy DEMATEL is to explain re-make relative strategies and improvements.

Matzler and Sauerwein [20] and Matzler *et al.* [19] explained two IPA model measurements of importance quality attributes, one is called the explicit importance, which is customers' self-expressional importance toward quality attributes; another one is known as the implicit importance, which is used coefficients of multiple regression equation to obtain customers' importance quality attributes. Matzler and Sauerwein [20] proved that customers' self-expressional importance is not a function of satisfaction quality attributes, and the implicit importance is a function of satisfaction quality attributes, which is obtained by using the multiple regression equation, meanwhile, performance as independent variable and overall satisfaction as dependent variable, so the coefficients obtained from the multiple regression equation are a better measurement for customers' importance toward quality attributes. Therefore, the multiple regression equation as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k + \varepsilon \quad (1)$$

and

Y = overall satisfaction ;

X_i = performance of item i's quality attribute (i = 1, 2,…, k)

This study turns the position axis of two-dimensional performance-importance matrix based on the traditional IPA model into the scale of importance based on regression coefficients. The scale of importance is the vertical axis based on the multiple regression coefficients (β), the scale of performance is the horizontal axis, and the split values of the vertical and horizontal axis is used for specifying four quadrants of quality attributes' performance and importance two-dimensional matrix. The definition of the four quadrants is remained the same as Martilla and James' [18] IPA model, so easy-explained and direct-interpreted traits are still remained in the modified IPA.

Usually, when undergoing improvements of quality attributes, quality attributes are assumed to be independent, and each of those will be improved directly in accordance with the IPA matrix. While quality attributes have a causal relationship, one quality attribute being improved will affect other quality attributes at the same time; therefore, the highly-influenced quality attributes should be improved first. As regards the causal relationship among the quality attributes and its influence toward decision-making and improvements, the methodology of fuzzy DEMATEL and the integration of IPA and the fuzzy DEMATEL are discussed in the following chapters in this study.

3. THE FUZZY DEMATEL METHOD

3.1 Decision Making Trial and Evaluation Laboratory

DEMATEL was developed by Battelle memorial association of Geneva research prominence (Gabus and Fontela, [4]; Fontela and Gabus, [3]), at that time, DEMATEL was used in studying the world's complicated problem, such as: race, hunger, environmental protection, and energy, etc. problems (Fontela and Gabus, [3]). In recent years, Japan, Korea, and Taiwan have broadly applied DEMATEL to solve problems in different fields, such as: Tamura et al. [25] adopted DEMATEL to explore the customer's insecure factor for food and improvement measures; Hajime et al. [6] integrated QFD,TRIZ and DEMATEL to resolve the design conflict of innovated product developing process; Nanayo and Toshiaki [27] adopted amended DEMATEL to process integrated evaluation on medical system; Kenichi and Yoshihiro [11] adopted DEMATEL to analyze the function and failure of snow melting equipment; Kim [12] integrated PCA,AHP and DEMATEL to evaluate the impact in cattle industry and agricultural information; Wu and Lee [29] adopted Fuzzy DEMATEL to develop the core ability of manager; Lin and Wu [17] applied Fuzzy DEMATEL to the group decision problem. Therefore, DEMATEL has been successfully adopted in many fields. The purpose of DEMATEL is to directly compare the interaction relationship between variables and use matrix to calculate the directly and indirectly causal relationships and influence level between variables, especially using the visual structural matrix and causal diagram to express the causal relationships and influence level between variables in the complicated system and assist making the decision. Therefore, DEMATEL can turn complicated system into a causal relationship with a clear structure[32][33], and simplify the relationships between variables in the complicated system to just cause and effect relation, through the interaction influence level between quantified variables to find out the core problem in the complicated system and the improvement direction. The study referred to the study of Lee et al., ([14][15]), and briefly describe the structure of DEMATEL and the calculating steps.

3.1.1 Define the variables and establish the measurement scale

List and define a complicated system's influence variables by using documentation exploration, brain storming or professional opinions, now assuming there are n variables that impact the complicated system. Establish the measurement scale of the pair-wise comparison of causal relationships and level between variables, the measurement scale respectively are 0, 1, 2, and 3 level, which respectively represent "no impact", "low impact", "high impact" and "great impact" (Lin and Wu [17]). In addition, the measurement scale is also divided into 0, 1, 2, 3, 4, and 5 level, which respectively represent "no impact", "very low impact" "low impact", "medium impact" "high impact" and "great impact" (Kim [12]), and Huang et al. [10] adopted 11 levels, 0, 1,…, 10, from "no impact" to "great impact".

3.1.2 Establish Direct-Relation Matrix

When the variable amount is n, through the survey questionnaire professional opinions to process pair-wise comparison on the variables depending on their influence relationships and level, then the direct-relation matrix, X, of n×n can be obtained. In direct-relation matrix, X, x_{ij} represents the variable, the level of i impact variable j, and the diagonal variable x_{ii} of direct-relation matrix, X is set to 0.

$$X = \begin{bmatrix} 0 & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & 0 \end{bmatrix} \tag{1}$$

At the same time, establish symbol matrix, S, to indicate the positive (+) or negative (-).

3.1.3 Calculate normalized direct-relation matrix

There are two calculation methods of normalized direct-relation matrix, such as: Wu and Lee [29], Lin and Wu [17], Kim [12], and Seyed-Hosseini et al. [24] all used the biggest sum of column vector as the normalized base; and Tzeng et al. [28] also used the biggest sum of column vector as the normalized base.

Set

$$\lambda = \frac{1}{\underset{1 \le i \le n}{Max}\left(\sum_{j=1}^{n} x_{ij}\right)} \text{ or } \lambda = Min\left[\frac{1}{\underset{1 \le i \le n}{Max}\left(\sum_{j=1}^{n} x_{ij}\right)}, \frac{1}{\underset{1 \le j \le n}{Max}\left(\sum_{i=1}^{n} x_{ij}\right)}\right] \quad (2)$$

From the calculation of equation (2) and (3), times direct-relation matrix, X, by λ to receive normalized direct-relation matrix, N.

$$N = \lambda X \quad (3)$$

Therefore, using normalized direct-relation matrix, N to go through the Markov Chain Matrix in the absorbing state to obtain the similar sub-stochastic matrix, according to the study of Goodman [6].

$$\lim_{k \to \infty} N^k = \mathrm{O} \text{ 且 } \lim_{k \to \infty}\left(\mathrm{I} + N + N^2 + \cdots + N^k\right) = \left(\mathrm{I} - N\right)^{-1} \quad (4)$$

O is null matrix, and I is identity matrix.

3.1.4 Direct / Indirect Relation Matrix:

Due to the normalized direct-relation matrix, N has the characteristic of equation (4), therefore, direct/ indirect relation matrix, T or total-relation matrix can be obtained from equation (5) (Huang et al., [10]). In addition, indirect relation matrix, H or total-indirect relation matrix can be obtained from equation (6) (Lin and Wu [17]).

$$T = \lim_{k \to \infty}\left(N + N^2 + \cdots + N^k\right) = N\left(I - N\right)^{-1} \quad (5)$$

$$H = \lim_{k \to \infty}\left(N^2 + N^3 + \cdots + N^k\right) = N^2\left(I - N\right)^{-1} \quad (6)$$

Set t_{ij} as the variable of direct/ indirect relation matrix, T, and i, j = 1, 2,…, n. The columns' sum of direct/ indirect relation matrix, T can be calculated from equation (7) and (8), and set D_i as the sum of column i, which represents variable, i is the cause that impact the sum of other variables; R_j is the sum of column j, which represents variable, i is the result and the sum impacted by other variables. D_i and R_j are obtained from direct/ indirect relation matrix, T, which include direct and indirect impact.

$$D_i = \sum_{j=1}^{n} t_{ij} \qquad \left(i = 1, 2, \cdots, n\right) \quad (7)$$

$$R_j = \sum_{i=1}^{n} t_{ij} \qquad (j = 1,2,\cdots,n) \tag{8}$$

3.1.5 Draw out causal diagram :

Define (D_k + R_k) as the prominence, and k = i = j = 1, 2,…, n, which means the overall level of this variable being impacted and the impact to others, according to this value it can show the core level of variable k in all the problems; and (D_k - R_k) is defined as the relation, which means the difference level of the variable being impacted and the impact to others, according to this value, it can show the attributed casual level of variable k in other problems, if it is a positive value, then the variable is the relation type, if it is a negative value, then the variable is the cause type. Causal diagram uses (D + R) as the transverse, and (D - R) as the longitudinal axis, and combine 2-D graphics constructed the symbol matrix, S, use the diagram to express the purpose of going through diagram to simplify the complicated casual relationship to the visual structure that is easy to understand, the decision maker can base on the variable located position to judge whether the variable shall be attributed to cause or effect type, and the level of variable being impacted and the impact to others, and plan suitable decision to solve the problem in accordance with the attributed type and impact level.

Respectively calculate the coordinate values (D_k + R_k, D_k - R_k) of various variables, and draw them out in the causal diagram. When D_k - R_k are positive values, the variable k is attributed to cause; if D_k - R_k are negative values, then variable k shall be attributed to effect type. When D_k + R_k are bigger, that means the bigger level of the variable impacted other variables is than other variables impacted the variable. It can be known from the causal diagram: if D_k - R_k are negative value and the values of D_k + R_k are very small, that means variable k is more independent, and there are less factors which will impact the variable; and when D_k - R_k is positive value and the values of D_k + R_k are very small, that means variable k also is independent, and can impact a few other variables; if D_k - R_k are negative values and the values of D_k + R_k are very big, that means variable k is the core problem required to be solved, however, it is not to directly improve the variable; when D_k - R_k are positive values and the values of D_k + R_k are big, which means variable k is the driving factor of solving the core problem, it shall be listed as the priority handling subject. Therefore, if the decision maker can base on the causal relationship of variable, and the interaction influence level between variables to find out the driving variable of the core problem in the complicated system, and plan the suitable decision to solve the problem in accordance with the attributed type and influence level.

3.2 Fuzzy Theory

3.2.1 The fuzzy logic

The Fuzzy Theory, introduced by Zadeh [31], is a mathematical way to describe the classes of materials in real life in order to make up the traditional shortcoming of binary logic. The theory is very useful for tackling ambiguities of human thought because it can convert ambiguities of human thought to specific values. In the fuzzy logic, each number between 0 and 1 indicates a partial truth, on the contrary, crisp set correspond to binary logic: 0 or 1; thus, fuzzy logic can handle ambiguities and imprecise judgments mathematically (Al-Najjar & Alsyouf [1]; Wu & Lee [29]). The essential definitions of the fuzzy logic are as the following (Wu & Lee [29])

In order to obtain the correct answer, after dealing problems with the fuzzy logic, an appropriate defuzzification method is still needed. The CFCS method (Converting Fuzzy data into Crisp Scores) proposed by Opricovic and Tzeng [28] is a defuzzification method, which takes into account not only each fuzzy number but also the overall factors under multi-criteria decision-making, to solve each fuzzy number. This method is based on the output of fuzzy set, which may convert fuzzy number into crisp scores. Comparing with other defuzzification methods, Wu and Lee [29] indicated that CFCS method can give a better crisp value. ◦ The CFCS method is based on the procedure of determining the left and right scores by fuzzy min and fuzzy max, and the total score is determined as a weighted average according to the membership function. The procedure includes four-step algorithms described as follows:

(1) Normalization:

$$r_i^{\max} = \max r_j^i ,\ l_i^{\min} = \min l_j^i ,\ \Delta_{\min}^{\max} = \min l_{ij}$$

Compute every a_j, $j = 1, \ldots, J$ ◦

$$x_{lj} = (l_{ij} - l_i^{\min}) / \Delta_{\min}^{\max}$$
$$x_{mj} = (m_{ij} - l_i^{\min}) / \Delta_{\min}^{\max}$$
$$x_{rj} = (r_{ij} - l_i^{\min}) / \Delta_{\min}^{\max} \quad (1)$$

(2) Compute left (ls) and right (rs) normalized value，$j = 1, \ldots, J$

$$X_j^{ls} = x_{mj} / 1 + x_{mj} - x_{lj}$$
$$X_j^{rs} = x_{rj} / 1 + x_{rj} - x_{mj} \quad (2)$$

(3) Compute total normalized crisp value，$j = 1, \ldots, J$

$$x_j^{crisp} = \left[x_j^{ls}(1 - x_j^{ls}) + x_j^{rs} x_j^{rs}\right] / \left[1 - x_j^{ls} + x_j^{rs}\right] \quad (3)$$

(4) Compute crisp values， $j = 1, \ldots, J$

$$f_{ij} = l_i^{\min} + x_j^{crisp} \Delta_{\min}^{\max} \quad (4)$$

3.2.2 The procedure of fuzzy DEMATEL method

The fuzzy DEMATEL combines Fuzzy Theory and Decision Making Trial and Evaluation Laboratory, which means that DEMATEL method is employed in a fuzzy environment. This method is practical for analyzing the causal relationship among variables and the influence degree of each variable. The analytical procedure of the fuzzy DEMATEL method is described as follows (Lin & Wu [17])：

Step 1: Set the decision goal and set up a committee.

Decision-making is the process of defining the decision goals, gathering relevant information, generating the broadest possible range of alternatives, evaluating the alternatives for advantages, selecting the optimal alternatives, and monitoring the results to ensure that the decision goals are achieved(Hess [7]). Thus, a decision goal is set up first. Subsequently, a committee is set up for gathering group knowledge for problem solving.

Step 2: Develop the evaluation criteria and design the fuzzy linguistic scale.

Evaluation criteria are developed based on expert opinions. However, the Evaluation criteria have nature of causal relationships and usually comprise several complicated aspects, so the DEMATAL method is employed to obtain variables from the complicated structure of causal relationships. This study adopts a fuzzy wording scale instead of traditional measuring scale to manage the variability of human thinking. The different influences are expressed by five degrees {Very high, High, Low, Very low and No Influence}. Please see Table 1 for equilateral triangle fuzzy functions.

Step 3: Acquire the assessments of decision-makers

To measure the relationship among criteria $C=\{C_i | i=1,2,...,n\}$, a decision group of p experts was asked to make sets of pair wise comparisons in terms of linguistic terms. Hence, p fuzzy matrices ($\tilde{Z}^{(1)}$, $\tilde{Z}^{(2)}$, …, $\tilde{Z}^{(p)}$), each corresponding to an expert and with triangular fuzzy numbers as its elements, were obtained. Denote $\tilde{Z}^{(K)}$ as：

$$\tilde{Z}^{(K)} = \begin{bmatrix} 0 & \tilde{z}_{12}^{(k)} \cdots \tilde{z}_{1n}^{(k)} \\ \tilde{z}_{21}^{(k)} & 0 \ \cdots \tilde{z}_{2n}^{(k)} \\ \vdots & \vdots \ \ddots \vdots \\ \tilde{z}_{n1}^{(k)} & \tilde{z}_{n2}^{(k)} \cdots 0 \end{bmatrix} ; \ k=1,2,\cdots,p, \qquad (5)$$

Where $z_{ij}^{(k)}=\left(l_{ij}^{(k)},m_{ij}^{(K)},u_{ij}^{(k)}\right)$, and without loss of generality, elements $\tilde{z}_{ii}^{(k)}(i=1,2,...,n)$ will be regarded as a triangular fuzzy number (0, 0, 0) whenever it is necessary. Fuzzy matrix $\tilde{Z}^{(K)}$ is called the initial direct-relation fuzzy matrix of expert K.

Step 4: Acquire the normalized direct-relation fuzzy matrix.

Let $\tilde{a}_i^{(k)}$ be the triangular fuzzy numbers,

$$\tilde{a}_i^{(k)} = \sum_{j=1}^{n} \tilde{z}_{ij}^{(k)} = \left(\sum_{j=1}^{n} l_{ij}^{(k)}, \sum_{j=1}^{n} m_{ij}^{(k)}, \sum_{j=1}^{n} u_{ij}^{(k)} \right)$$

and

$$r^{(k)} = \max_{1 \le i \le n} \left(\sum_{j=1}^{n} u_{ij}^{(k)} \right)$$

The linear scale transformation is then used as a normalization formula to transform the criteria scales into comparable scales. The normalized direct-relation fuzzy matrix of expert k, denoted as X(k), is given by

$$\tilde{X}^{(k)} = \begin{bmatrix} \tilde{x}_{11}^{(k)} & \tilde{x}_{21}^{(k)} & \cdots & \tilde{x}_{1n}^{(k)} \\ \tilde{x}_{21}^{(k)} & x_{22}^{(k)} & \cdots & \tilde{x}_{2n}^{(k)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1}^{(k)} & \tilde{x}_{22}^{(k)} & \cdots & \tilde{x}_{nn}^{(k)} \end{bmatrix} ; \; k = 1,2,\cdots,p, \tag{6}$$

Where

$$\tilde{x}_{ij}^{(K)} = \tilde{z}_{ij}^{(k)} \Big/ r^{(k)} = \left(l_{ij}^{(k)} \Big/ r^{(k)}, m_{ij}^{(k)} \Big/ r^{(k)}, u_{ij}^{(k)} \Big/ r^{(k)} \right)$$

As that in crisp DEMATEL method, we assume at least one I such that $\sum_{j=1}^{n} u_{ij}^{(k)} < r^{(k)}$. This assumption is well satisfied in practical cases. Through basic calculation of the matrix, the average matrix $\tilde{X}$ is obtained.

Step 5: Establish and analyze the structural model.

To compute the total-relation fuzzy matrix $\tilde{T}$, we have to ensure the convergence of $\lim_{w \to \infty} \tilde{X}^w = 0$ in advance. The elements of $\tilde{X}^w$ are also triangular fuzzy matrix, as follows：

$$\tilde{X}^{(w)} = \begin{bmatrix} \tilde{x}_{11}^{(w)} & \tilde{x}_{21}^{(w)} & \cdots & \tilde{x}_{1n}^{(w)} \\ \tilde{x}_{21}^{(w)} & x_{22}^{(w)} & \cdots & \tilde{x}_{2n}^{(w)} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1}^{(w)} & \tilde{x}_{22}^{(w)} & \cdots & \tilde{x}_{nn}^{(w)} \end{bmatrix} \text{，其中，} \tilde{x}_{ij}^{(w)} = \left(l_{ij}^{(w)}, m_{ij}^{(w)}, u_{ij}^{(w)} \right)$$

Theorem 3.1. :

We further define three matrices,

$$\left[l_{ij}^{(w)}\right]=\begin{bmatrix} l_{11}^{(w)} & l_{12}^{(w)} & \cdots & l_{1n}^{(w)} \\ l_{21}^{(w)} & l_{22}^{(w)} & \cdots & l_{2n}^{(w)} \\ \vdots & \vdots & \ddots & \vdots \\ l_{n1}^{(w)} & l_{22}^{(w)} & \cdots & l_{nn}^{(w)} \end{bmatrix}$$

$$\left[m_{ij}^{(w)}\right]=\begin{bmatrix} m_{11}^{(w)} & m_{12}^{(w)} & \cdots & m_{1n}^{(w)} \\ m_{21}^{(w)} & m_{22}^{(w)} & \cdots & m_{2n}^{(w)} \\ \vdots & \vdots & \ddots & \vdots \\ m_{n1}^{(w)} & m_{22}^{(w)} & \cdots & m_{nn}^{(w)} \end{bmatrix}$$

and

$$\left[u_{ij}^{(w)}\right]=\begin{bmatrix} u_{11}^{(w)} & u_{12}^{(w)} & \cdots & u_{1n}^{(w)} \\ u_{21}^{(w)} & u_{22}^{(w)} & \cdots & u_{2n}^{(w)} \\ \vdots & \vdots & \ddots & \vdots \\ u_{n1}^{(w)} & u_{22}^{(w)} & \cdots & u_{nn}^{(w)} \end{bmatrix}$$

then $\left[l_{ij}^{(w)}\right]=X_l^w,\left[m_{ij}^{(w)}\right]=X_m^w,\left[u_{ij}^{(w)}\right]=X_u^w$

Theorem 3.2. : It holds that $\lim_{w\to\infty} X^w = \mathrm{O}$, and $\lim_{w\to\infty}\left(\mathrm{I}+X+X^2+\cdots+X^k\right)=\left(\mathrm{I}-X\right)^{-1}$; where O is null matrix and I is identity Matrix.

Theorem 3.3. : According to the crisp case, we define the total-relation fuzzy matrix $\tilde{T}$ as

$$\tilde{T}=\lim_{w\to\infty}\left(\tilde{X}+\tilde{X}^2+\cdots+\tilde{X}^k\right)=\tilde{X}\left(I-\tilde{X}\right)^{-1} \tag{7}$$

令

$$\tilde{T}=\begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & t_{22} & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ t_{n1} & t_{n2} & \cdots & \tilde{t}_{nn} \end{bmatrix}$$

Where $\tilde{t}_{ij}=\left(l_{ij}'',m_{ij}'',u_{ij}''\right)$, then

$$Matrix\left[l_{ij}''\right]=X_l\times\left(I-X_l\right)^{-1}$$

$$Matrix\left[m_{ij}''\right]=X_m\times\left(I-X_m\right)^{-1}$$

$$Matrix\left[u_{ij}^{"}\right] = X_u \times \left(I - X_u\right)^{-1}$$

According to the above theorems, the matrices $\left[l_{ij}^{(w)}\right]$, $\left[m_{ij}^{(w)}\right]$, $\left[u_{ij}^{(w)}\right]$ are obtained. These matrices are able to construct to be the total-relation fuzzy matrix, and then the matrix can be defuzzificated by applying the CFCS method and computing four-step algorithms to obtain crisp value, which is converted from fuzzy numbers, determining the left and right scores by fuzzy min and fuzzy max, and the total score is determined as a weighted average.

4. INTEGRATION OF IPA AND FUZZY DEMATEL

When undergoing improvements of quality attributes, quality attributes are assumed to be independent, and each of those will be improved directly in accordance with the IPA matrix. While quality attributes have causal relationships, one quality attribute being improved will affect other quality attributes at the same time; therefore, the highly-influenced quality attributes should be improved first. To understand the causal relationship among the quality attribute, the two-dimension causal diagram based on the analytical results of the fuzzy DEMATEL can be a reference. The average value of each axis can be divided into four quadrants: Quadrant I represents an area in which listed quality attributes are with high prominence and relation, and it means the quality attributes are the core issues and will affect other quality attributes, which should be listed as first improvements; Quadrant II represents an area in which listed quality attributes are with low prominence but high relation, and it means the quality attributes are highly independent and will affect less quality attributes; Quadrant III represents an area in which listed quality attributes are with low prominence and relation, and it means the quality attributes are highly independent and will be affected by less quality attributes; Quadrant IV represents an area in which listed quality attributes are with high prominence but low relation, and it means the quality attributes are the core issues and will be affected by other quality attributes. The quality attributes in Quadrant III、IV can be neglected and viewed as independent quality attributes because of those prominence lower than the average and with little influence. Therefore, the integration of IPA and fuzzy DEMATEL can be divided into two parts and each with four strategies, as in Table2：

4. CASE STUDY AND DISCUSSION

This study uses a Taiwanese bank as a case study, and employs IPA and the fuzzy DEMATEL model to improve customer satisfaction. The bank in the case study is one of the first leading banks in Taiwan, it has been operating 65 years, its total capital is NTD 500 billion, and its performance is growing steadily. In this research, there are eight questions about service satisfaction shown in the questionnaire which is mainly designed for the customers traded with the bank in 2010. They include: employees can provide timely services (Q1), service facilities attractive (Q2), banks provide the service to meet all the needs of customers (Q3), banks are reliable (Q4), employees are polite (Q5), employees can be expected to understand customers' needs (Q6), employees can provide customers with individual care and service without limitation of service time (Q7), employees have a neat appearance and service (Q8). The questionnaire is combined with IPA and the fuzzy DEMATEL mode to analyze, which could provide the direction for managers to identify improvements and then to enhance the competitiveness of the company.

4.1 Constructing Questionnaire and Survey of IPA and fuzzy DEMATEL

IPA questionnaire of this study is designed to understand customers' actual perception toward quality attributes in order to examine the actual performance of companies. In the questionnaire, there are check boxes for each question about satisfaction, and satisfaction are classified as "1" meant "very dissatisfied "and "7" meant "very satisfied. " In addition, there are also questions about importance of product and service quality toward customers in order to understand customers' priority and their value, and importance is classified as "1" meant "very unimportant" and "7" meant "very important." Moreover, the customers are asked to evaluate for the overall performance of the company at the end of the questionnaire, and the scale of scores is from 1 to 7 points, which is as the assessment of the overall satisfaction.

The design of Fuzzy DEMATEL questionnaire adopts experts' opinions, and 15 bank executives answer the eight questions (Q1 ~ Q8) to develop the direct relation matrix. The direct relation measurement scale is the fuzzy linguistic scale, not the traditional measurement scale. There are five different linguistic expressions representing five different degree of influence in this direct relation measurement scale, namely, {Very high, High, Low, Very low, No}. This study not only uses customer satisfaction information and the modified IPA model to establish the matrix of importance and satisfaction, but also employs Fuzzy DEMATEL to analyze direct and indirect relations, and then to point out key issues and improvements.

4.2 Analyzed Results

Multiple regression analysis is used to obtain importance of each question and is used as a standard to judge the level of the overall satisfaction. Referring to Table 3, the significant factors (P value <0.05) affecting the overall satisfaction are: banks are reliable (Q4), employees can provide customers with individual care and service without limitation of service time (Q7). The regression coefficient can represent the relative importance. According to the modified IPA model, the horizontal axis is performance and the vertical axis is implicit importance, the value of regression coefficient, and then the two-dimensional matrix of importance - performance is obtained. This matrix is divided into four groups of the eight questions, which are the references for the bank to make strategies of developments. Table 4 is the data obtained through using the modified IPA model. In addition to the modified importance of the regression coefficients and the performance for each question, there are also included the priority of improvements. The quality attributes falling into "Concentrate here" quadrant means these quality attributes must be improved immediately, and the order of quality attributes to be improved are: employees can provide timely services (Q1) and employees can provide customers with individual care and service without limitation of service time (Q7); the quality attribute falling into "Keep up the good work" quadrant is banks are reliable (Q4) ; the quality attributes falling into "Possible overkill" quadrant are service facilities attractive (Q2), banks provide the service to meet all the needs of customers (Q3), employees are polite (Q5), and employees can be expected to understand customers' needs (Q6). The quality attributes in the "Low priority" quadrant is employees have a neat appearance and service (Q8).

The design of Fuzzy DEMATEL questionnaire adopts experts' opinions, and 15 bank executives answer the eight questions (Q1 ~ Q8) to analyze eight variables and the causal relationship between the degree of mutual influence. There are five different linguistic expressions representing five different degree of influence in this direct relation measurement scale, from No Influence to Very High Influence, which let those experts express their opinion about the degree of influence, shown as in Table 5.

According to Table 1, The fuzzy scale of Table 5 can be turned into the direct-relation matrix with fuzzy value. In accordance with the suggestion of Lin and Wu [18], after using formula (2) to establish the direct-relation matrices X_l, X_m and X_u, these three matrices can be computed individually by using DEMATEL.

Based on Formula (3), Lin and Wu's [18] method is adopted to standardize the direct-relation fuzzy matrices. $l \le m \le u$, the linguistic value and the max value of u is the standardized basis, and the value of r is 1/6.75; meanwhile, $\tilde{x}_{ij}^{(K)} = \tilde{z}_{ij}^{(k)} / r^{(k)} = \left(l_{ij}^{(k)} / r^{(k)}, m_{ij}^{(k)} / r^{(k)}, u_{ij}^{(k)} / r^{(k)} \right)$ is employed to obtained the direct-relation fuzzy matrices of X_l 、X_m and X_u. According to Theorem 3.1., the fuzzy matrix X is destructed into X_l、 X_m、 X_u. When the convergence of the standardized direct-relation fuzzy matrices is close to infinity, the matrices also are close to a zero matrix. Therefore, the total-relation matrix of X_l、 X_m、 X_u can be obtained from formula (7). The total-relation matrix of X_l、 X_m、 X_u is be integrated and then the total-relation fuzzy matrix T. Following formula (1) to (4) to defuzzifize, the linguistic value of the total-relation fuzzy matrix T turns into the crisp case. Because of the complication of causal relationships among quality attributes, the influential degree of causal relationships lower than 0.25 can be viewed as no causal relationships, shown as Table 7.

The causal relationship of each quality attributes is clear after using Fuzzy DEMATEL method. Take employees can provide timely services (Q1) as an example. From Table 7 , it shows that employees can provide timely services (Q1) affects banks are reliable (Q4) directly, and the influential degree is 0.28; the influential degree of employees can provide customers with individual care and service without limitation of service time (Q7) is 0.28.

Next, follow formula (8) and (9) to compute D_i of every row and R_i of every column to obtain prominence ($D_i + R_i$) and relation ($D_i - R_i$), shown as Table 8.

The average value is obtained by adding prominence ($D_i + R_i$) and relation ($D_i - R_i$) and subtracting with 8, and this average value is viewed as the estimated value of centered causal matrix, and the value can divide the matrix into four quadrants, shown as Figure 3. According to Figure 3, the quality attributes with high prominence and high relation are employees are polite (Q5), employees can be expected to understand customers' needs (Q6), and employees can provide customers with individual care and service without limitation of service time (Q7), which means these three quality attributes are the core quality attributes affecting others; the quality attributes with high prominence but low relation are banks provide the service to meet all the needs of customers (Q3) and banks are reliable (Q4), which means these two are the core quality attributes affected by others. As for the rest of quality attributes, they can be neglected and viewed as independent attributes because their prominence are lower than the average 3.390.

5. CONCLUSION

Since Martilla and James [19] first used IPA method in the marketing strategy on development companies, many scholars have researched relative field and modify their original model to help managers to solve practical problems. However, there are still hidden problems with these models needed to be discussed, including: (1) the positive importance quality attributes does not take the impact of performance quality attributes and the overall satisfaction into account; (2) when there are causal relationships among quality attributes, the quality attributes assumed independent in the traditional IPA model will lead to wrong decision-making; (3) Respondents are forced to choose the only answer which represents specific value in the traditional questionnaires, and the results of such questionnaire cannot truly reflect how the respondents feel. In this study, multiple regression analysis is employed to establish the performance quality attributes and implicit importance of the overall satisfaction, and then to find the factors affecting the overall satisfaction. Moreover, regression coefficients are viewed as importance, and higher value of coefficients, higher importance quality attributes to establish the modified IPA model. In addition, considering fuzziness of human thinking, fuzzy DEMATEL is used to map out causal relationships among quality attributes, and then to identify core issues and improvements.

The integration of the modified IPA model combined with fuzzy DEMATEL method in this study not only diminishes the hidden problems of the traditional model, modified the causal relationships and the degree of mutual influence of quality attributes in IPA model, but also identifies directions and focuses of quality attributes to helping managers to solve problems with minimal resources. This study uses a first leading Taiwanese bank as a case study, and employs the IPA which is modified by multiple regression analysis and the fuzzy DEMATEL model. The methodology is provided managers with a more reasonable assessment of importance and performance.

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Table 1 The correspondence of linguistic terms and values

Linguistic terms	Linguistic values
Very high influence (VH)	(0.75, 1.0, 1.0)
High influence (H)	(0.5, 0.75, 1.0)
Low influence (L)	(0.25, 0.5, 0.75)
Very low influence (VL)	(0, 0.25, 0.5)
No influence (No)	(0, 0, 0.25)

Table 3：Multi regression coefficients of performance and the overall satisfaction

Model	Un-standardized coefficients		t	Significant
	B	Std. Error		
(notation)	0.761	0.359	2.117	0.035*
Q1	0.126	0.069	1.825	0.069
Q2	0.074	0.056	1.335	0.183
Q3	0.089	0.053	1.684	0.094
Q4	0.179	0.066	2.732	0.007**
Q5	0.072	0.073	0.984	0.326
Q6	0.105	0.065	1.608	0.109
Q7	0.169	0.073	2.300	0.022*
Q8	0.057	0.073	0.784	0.434

Note: Adjusted R Square: 0.982; "*": P-value < 0.05; "**" P-value < 0.01,"***" P-value < 0.00

Table 2: The integration of IPA and fuzzy DEMATEL

Quality attributes	Quadrant	Affected positively by other quality attributes 'quadrant	Strategy (if influence is negative, opposite strategy is adopted)
High prominence high relation	Concentrate here	Keep up the good work	Keep up with good performance of the influential quality attributes; enhance competitiveness of the quality attributes and upgrade the performance of other quality attributes
		Low priority	Keep up with good performance of the influential quality attributes; enhance competitiveness of the quality attributes and upgrade the performance of other quality attributes
		Possible overkill	Rethink the influence and improvements of the quality attributes
	Keep up the good work	Concentrate here	Improve right away the influential quality attributes; enhance competitiveness of the quality attributes and upgrade the performance of other quality attributes instantly
		Low priority	Improve right away the influential quality attributes; enhance competitiveness of the quality attributes and upgrade the performance of other quality attributes instantly
		Possible overkill	Rethink the influence and improvements of the influential quality attributes
	Low priority	Concentrate here	Improve right away the influential quality attributes; enhance competitiveness of the quality attributes and upgrade the performance of other quality attributes instantly
		Keep up the good work	Rethink the influence and improvements of the quality attributes
		Possible overkill	Rethink the influence and improvements of the quality attributes
	Possible overkill	Concentrate here	Rethink the influence and improvements of the quality attributes
		Keep up the good work	Rethink the influence and improvements of the quality attributes
		Low priority	Rethink the influence and improvements of the quality attributes

Quality attributes	Quadrant	Affected positively by other quality attributes 'quadrant	Strategy (if influence is negative, careful evaluation is adopted)
High prominence low relation	Concentrate here	Keep up the good work	Improve right away the influential quality attributes; enhance competitiveness of the quality attributes and upgrade the performance of other quality attributes instantly
		Low priority	Improve right away the influential quality attributes; enhance competitiveness of the quality attributes and upgrade the performance of other quality attributes instantly
		Possible overkill	Rethink the influence and improvements of the quality attributes
	Keep up the good work	Concentrate here	Improve right away the influential quality attributes; enhance competitiveness of the quality attributes and upgrade the performance of other quality attributes instantly
		Low priority	Improve right away the influential quality attributes; enhance competitiveness of the quality attributes and upgrade the performance of other quality attributes instantly
		Possible overkill	Rethink the influence and improvements of the quality attributes
	Low priority	Concentrate here	Improve right away the influential quality attributes; enhance competitiveness of the quality attributes and upgrade the performance of other quality attributes instantly
		Keep up the good work	Rethink the influence and improvements of the quality attributes
		Possible overkill	Rethink the influence and improvements of the quality attributes
	Possible overkill	Concentrate here	Rethink the influence and improvements of the quality attributes
		Keep up the good work	Rethink the influence and improvements of the quality attributes
		Low priority	Rethink the influence and improvements of the quality attributes

Table 4：the results of the modified IPA model

Notation	Performance	Importance (Implicit)	STRATEGY
Q1	6.060	0.126	C
Q2	5.300	0.074	P
Q3	5.108	0.089	P
Q4	5.292	0.179	K
Q5	5.312	0.072	P
Q6	5.344	0.105	P
Q7	5.576	0.169	C
Q8	5.864	0.057	L

Note: C= Concentrate here; K= Keep up the good work; L= Low priority; P= Possible overkill

Table 5: the results of experts' opinion

T	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Q1	NO	NO	H	H	VL	H	H	NO
Q2	NO	NO	NO	H	L	L	L	NO
Q3	H	NO	NO	H	L	L	L	NO
Q4	H	H	H	NO	L	H	H	L
Q5	VL	VL	VL	L	NO	VL	H	H
Q6	H	VL	VL	VH	H	NO	H	NO
Q7	H	L	H	H	H	VH	NO	L
Q8	NO	VL	NO	H	H	L	L	NO

Table 6: Total-relation matrix

T	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Q1	0.17	0.11	0.24	0.29	0.20	0.28	0.28	0.11
Q2	0.12	0.09	0.11	0.25	0.20	0.20	0.21	0.09
Q3	0.25	0.10	0.14	0.28	0.22	0.23	0.24	0.10
Q4	0.28	0.23	0.26	0.25	0.27	0.31	0.32	0.19
Q5	0.17	0.14	0.16	0.24	0.15	0.19	0.26	0.20
Q6	0.27	0.15	0.19	0.33	0.27	0.22	0.30	0.12
Q7	0.29	0.20	0.27	0.34	0.30	0.34	0.24	0.19
Q8	0.13	0.13	0.12	0.27	0.24	0.22	0.23	0.10

Table 7: direct/indirect –relation matrix ($T_{cut=0.25}$)

$T_{cut=0.25}$	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Q1				0.29		0.28	0.28	
Q2								
Q3				0.28				
Q4	0.28		0.26		0.27	0.31	0.32	
Q5							0.26	
Q6	0.27			0.33	0.27		0.30	
Q7	0.29		0.27	0.34	0.30	0.34		
Q8				0.27				

Table 8：Coefficients of prominence and relation

Notation	***D***	***R***	***D* + *R***	***D* - *R***
Q1	1.675	1.697	3.372	(0.023)
Q2	1.272	1.169	2.441	0.103
Q3	1.561	1.504	3.065	0.057
Q4	2.095	2.220	4.315	(0.124)
Q5	1.515	1.847	3.362	(0.331)
Q6	1.855	1.989	3.844	(0.134)
Q7	2.160	2.045	4.205	0.114
Q8	1.444	1.074	2.519	0.370

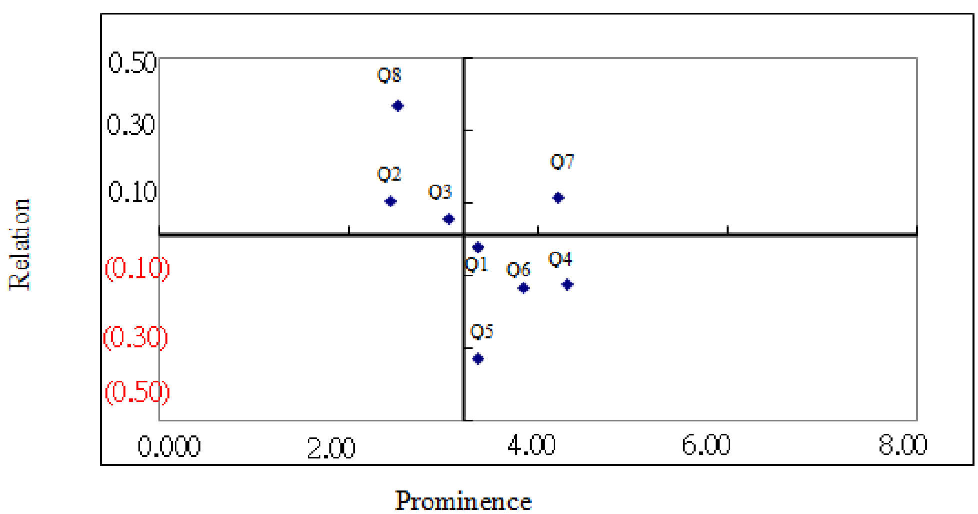

Figure 1: Causal Matrix of Order-winner Criteria